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COLLABORATIVE RESEARCH: Drillsite Reconnaissance and Snow Chemistry Survey in Denali National Park

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Kreutz, Karl - Principal Investigator
Title:
COLLABORATIVE RESEARCH: Drillsite Reconnaissance and Snow Chemistry Survey in Denali National Park

Project Participants

Senior Personnel

Name: Kreutz, Karl
Worked for more than 160 Hours: Yes
Contribution to Project:

Post-doc

Name: Osterberg, Erich
Worked for more than 160 Hours: Yes
Contribution to Project:
Erich is a postdoc at Dartmouth College (former UMaine PhD student) who was part of the 2008 Denali expedition. Erich participated in all aspects of the expedition, and collected snow samples for chemical and isotopic analysis as part of his Dartmouth postdoc research.

Graduate Student

Name: Gross, Benjamin
Worked for more than 160 Hours: Yes
Contribution to Project:
Ben was a field research assistant for the 2008 Denali expedition, and will be using geochemical data collected on the trip as part of his MS thesis at UMaine.

Undergraduate Student

Name: Campbell, Seth
Worked for more than 160 Hours: Yes
Contribution to Project:
Seth was a field research assistant for the 2008 Denali expedition, and will be using geophysical/glaciological data collected on the trip for his MS thesis at UMaine.

Name: Lurie, Max
Worked for more than 160 Hours: Yes
Contribution to Project:
Field and laboratory assistant

Name: Volkening, Kevin
Worked for more than 160 Hours: Yes
Contribution to Project:
Field assistant

Name: Callahan, Tom
Worked for more than 160 Hours: Yes
Contribution to Project:

Field and laboratory assistant

Technician, Programmer

Name: Waskiewicz, Michael

Worked for more than 160 Hours: Yes

Contribution to Project:

Mike is a professional field associate/ice core driller working through ICDS, and was on the 2008 Denali expedition to set up automatic weather stations and be responsible for ice core drilling and drill maintenance.

Name: Lisnet, Ronald

Worked for more than 160 Hours: Yes

Contribution to Project:

Ron is a videographer from the UMaine Department of Public Relations, and joined the 2008 Denali trip with funding from UMaine to shoot video and still pictures of the trip for educational outreach and promotional purposes.

Name: Introne, Douglas

Worked for more than 160 Hours: Yes

Contribution to Project:

Doug manages the UMaine Stable Isotope Laboratory, and is responsible for the isotope analysis of all snow and firn core samples collected on the 2008 Denali expedition.

Name: Handley, Michael

Worked for more than 160 Hours: Yes

Contribution to Project:

Mike manages the UMaine ICP_MS Facility, and is responsible for trace element and isotope analysis of all snow and firn core samples collected on the 2008 Denali expedition.

Name: Sneed, Sharon

Worked for more than 160 Hours: No

Contribution to Project:

Sharon manages the UMaine Ion Chromatography Laboratory, and is responsible for the major ion analysis of all snow and firn core samples collected on the 2008 Denali expedition.

Other Participant

Research Experience for Undergraduates

Organizational Partners

University of New Hampshire

U.S. Army Cold Regions Research and Enginering Laboratory

UNAVCO, Inc.

University of Wisconsin-Madison

Dartmouth College

The University of Montana

A University of Montana undergraduate (Kevin Vokering) participated in the 2009 Denali field work.

Other Collaborators or Contacts

Activities and Findings

Research and Education Activities: (See PDF version submitted by PI at the end of the report)

Findings: (See PDF version submitted by PI at the end of the report)

Training and Development:

In 2008, PhD student Eric Kelsey, who had no prior experience in such a project, participated in every aspect of this project, which served as a robust training and developmental opportunity in paleoclimatology, expedition preparation, and field logistics, and sample collection. The organization and shipment of scientific equipment from multiple academic institutions and agencies to Alaska was orchestrated by Mr. Kelsey. The daily tasks required while living, working, and traveling on a glacier for two and a half weeks were all new learning and training exercises. Mr. Kelsey learned the scientific process for the collection of ultraclean samples from snowpits, and manually drilling shallow firn cores. In summer and fall 2008, Mr. Kelsey learned how to analyze stable isotopes and ions in the
snow samples and firn core he helped extract. The results helped him construct a picture of recent weather and pollution affecting DNP as well as common sources and atmospheric pathways of trace elements, rare earth elements, and ions.

In 2008, UMaine undergraduate student Seth Campbell participated in the preparation, field work, and subsequent sample and data processing. Mr. Campbell has extensive prior experience in mountaineering, and completed the Juneau Icefield research field camp in summer 2007. He used various data collected on the trip, particularly the GPS and GPR data, for his MS thesis at UMaine. UMaine MS student Ben Gross also participated in the 2008 field program, and used glaciochemical data produced at UMaine (water stable
isotopes, trace element concentrations, and Pb isotopes) as part of his MS thesis completed in fall 2008.

In 2009, undergraduate students Max Lurie (University of Maine) and Tom Callahan (Dartmouth College), both of whom had no prior experience in such a project, participated in the preparation and completion of every aspect of the field expedition, and will continue their educational training by completing undergraduate theses on aspects of this project. This project served as a robust training and developmental opportunity in paleoclimatology, expedition preparation, and field logistics, and sample collection. The daily tasks required while living, working, and traveling on a glacier for two and a half weeks were all new learning and training exercises. Max and Tom learned the scientific process for the collection of ultraclean samples from snowpits, collection of GPR profiles, GPS velocity data, and installing an AWS. This summer and fall, Max will learn the process of laboratory analysis and interpretation of stable isotope data from the snow pits, while Tom will learn statistical analyses and interpretation of meteorological data, both in the larger context of understanding the glaciochemical paleoclimate record from Denali.

In 2009, undergraduate student Kevin Volkening (Montana State University) had previous glaciological experience through the Juneau Icefield research field camp and recreational mountaineering, but this was his first experience collecting GPR data and establishing an AWS system. Furthermore, this was Kevin?s first in-depth educational experience in paleoclimate studies, given his electrical engineering major at MSU. Kevin intends to pursue the development of the digital elevation model of the Kahiltna Pass region as part of our ice core site evaluation.

In 2009, UMaine MSc student Seth Campbell participated in the preparation, field

work, and subsequent sample and data processing. Mr. Campbell has extensive prior experience in mountaineering, and completed the Juneau Icefield research field camp in summer 2007, and was a member of the Denali expedition in 2008. He will be using various data collected on the trip, particularly the GPS and GPR data, for his MSc thesis (Kreutz, advisor) investigating the flow dynamics of the upper Kahiltna Glacier. His experience using GPR for glaciological studies on Denali in 2008 directly led to his accepting a position in the glaciology group at CRREL in Hanover, NH.

Outreach Activities:

Two presentations about global climate change and our paleoclimate research in DNP were given while our team was in Talkeetna, Alaska during 2008. On May 4, prior to flying into Denali basecamp, Dr. Erich Osterberg (Dartmouth College) gave the first presentation at the National Park Sevice Ranger Station in Talkeetna. In his talk, he discussed ice core research and global climate change, placed our current research activities into a large contect, and described our current field research and scientific goals. The large audience
(> 40 people) asked numerous questions and were appreciative of the informative presentation. After our field expedition, Ben Gross (University of Maine) gave another talk held at Talkeetna Air Taxi. The content was similar, and he was able to talk about how our expedition transpired and what we learned thus far. His talk was similarly well received.

In 2008, The UMaine Department of Public Relations supported the inclusion of a staff videographer, Ron Lisnet, at the beginning of the expedition to film various aspects of the science, logistics, and field life. Ron is currently editing the film, still photographs, and interviews collected on the trip, and integrating it with additional filming to be done in UMaine labs. We intend to produce several short video segments, suitable for web outreach, that convey the objectives and results of the project. Video from the 2008 expedition has been used extensively in promotional materials for UMaine, including televised advertisements during UMaine sporting events, on local TV stations (notably being shown during ?American Idol?), and on the UMaine website homepage.

Since the completion of the 2008 field season, our field program has been featured in two newsletters. One from the ?Spheres? newsletter published by the Institute for the Study of Earth, Oceans, and Space at UNH
(http://www.eos.sr.unh.edu/pdf/spr08_spheres.pdf) and a second in ?Field Notes? published by the CH2M Hill Polar Services
(http://www.polar.ch2m.com/Files/PDFs/NewsletterJuneJuly2008.pdf)

On May 3, 2009, prior to flying into Denali basecamp, Dr. Erich Osterberg (Dartmouth College) gave a presentation at the National Park Service Ranger Station in Talkeetna. In his talk, he discussed the initial scientific results from the first field season (2008), and the team?s plans for the second season (2009), and put them into the larger context of climate change research. The audience (> 40 people) asked numerous questions and was appreciative of the informative presentation.

The science team met with outreach coordinators for the National Park Service in Talkeetna after the 2009 field season, and is currently in discussions with them about how best to communicate our scientific findings to the public at Denali National Park. Eric Kelsey (University of New Hampshire) is currently developing a web site detailing the results of this project, and we will coordinate with the Park Service to provide appropriate links to and from their web site.

Journal Publications

Eric Kelsey, Cameron Wake, Karl Kreutz, Erich Osterberg, "Ice layers as an indicator of summer warmth and atmospheric blocking in Alaska", Journal of Glaciology, p. , vol. , (2009). Submitted,

Eric Kelsey, Cameron Wake, Kaplan Yalcin, Karl Kreutz, "Eclipse ice core accumulation and stable isotope variability as an indicator of North Pacific climate", Journal of Glaciology, p. , vol. , (2009). Submitted,

Books or Other One-time Publications

Web/Internet Site

URL(s):

http://www.ncdc.noaa.gov/paleo/icecore/trop/denali/denali.html

Description:

Project data archive at NCDC Paleoclimate website

Other Specific Products

Product Type:

Audio or video products

Product Description:

We have developed several video products using footage shot during the 2008 Denali expedition by UMaine videographer Ron Lisnet. They generally are short (2-5 minute) segments with specific educational themes, and are targeted at different audiences (e.g., K-12 students, University promotion and student recruitment).

Sharing Information:

We plan to distribute the video segments through the UMaine portion of iTunesU.

Contributions

Contributions within Discipline:

We expect that results of the 2008 and 2009 Denali expeditions will make significant contributions to our knowledge of North Pacific climatology, Arctic glaciology in general and in Denali National Park. In particular, the glaciochemical and geophysical data we collected are the first of their kind (to our knowledge) from central Alaska, and therefore will be key in understanding the local glaciological/climatological response to recent Arctic warming.

Contributions to Other Disciplines:

Outside of our disciplines of glaciology and climatology, we expect that our results from the 2008 and 2009 Denali expeditions will contribute to regional knowledge of present and past climatology, which should be of use to, at the least, ecologists and hydrologists.

Contributions to Human Resource Development:

The 2008 and 2009 Denali expeditions provided a unique opportunity for several UMaine students and technical staff. In particular, two undergraduate students (Seth Campbell and Max Lurie), and two graduate students (Ben Gross and Seth Campbell) were along in the field, and used the data as part of their MS theses. Erich Osterberg, a former UMaine PhD student and now Dartmouth postdoc, was also along, and will use samples and data for the trip as part of his postoc research program. Several UMaine technicians (Mike Handley, Doug Introne, and Sharon Sneed) will have the opportunity to participate in the project through sample analysis and interpretation. Last, Ron Lisnet, a professional videographer at UMaine, accompanied us on the trip to shoot educational and promotional video footage. This was Ron?s first trip to a glaciated region, and he now doubt benefited greatly from the experience.

Contributions to Resources for Research and Education:

The PI (Kreutz) plans to used data and ideas from the 2008 Denali expedition in two courses during the Fall 2008 semester: ERS200 Earth Systems and ERS315 Sedimentology and Stratigraphy. PI Kreutz is also using the Denali datasets as part of two new undergraduate courses to be offered during the Spring 2010 semester and the May 2010 term: ERS 201:

Global Environmental Change, and ERS 150: Earth?s Climate: Past, Present, Future. In addition, the video footage shot by Ron Lisnet is being produced into several online video segments highlighting Arctic climate change, glaciology, field research, field life, educational and student opportunities, and student recruitment efforts.

Contributions Beyond Science and Engineering:

Conference Proceedings

Categories for which nothing is reported:

Any Book

Contributions: To Any Beyond Science and Engineering

Any Conference

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MAJOR FINDINGS:

Kahiltna Pass Deep Ice Core Site Evaluation

The ideal weather and visibility conditions during the 2009 field season allowed the team to visually confirm that Kahiltna Pass is an excellent potential deep ice core site. Kahiltna Pass is a domed plateau region surrounded by a low ridge on three sides, which offers protection from strong winds (Figure 5). The site resembles the Eclipse Icefield deep ice core site in the St. Elias Mountains (Yukon Territory), where some of the team members have previously worked. Following a wind storm on May 10-13, during which all climbers evacuated from the summit approach due to >70 mph sustained winds, the team noticed abundant sastrugi lower on the Kahiltna Glacier, but little evidence of wind scour on the Kahiltna Pass dome. Conversations with passing climbers confirmed that the winds experienced by the science team camped at Kahiltna Pass were mild compared to those encountered both higher and lower on the mountain.

Automatic Weather Station Data

Tom Callahan (Dartmouth College) will begin to analyze the 2008-2009 meteorological station data as part of his undergraduate honors thesis. He will evaluate the relationship between base camp AWS data with other nearby meteorological station data, and will seek to correlate storms and other weather events with glaciochemical data from the snow pits.

Ground Profiling Radar and GPS Surveys

Seth Campbell, a University of Maine MSc student and field team member, has recently begun analysis of the 2009 GPR data and GPS velocity data from Kahiltna Pass. Initial results indicate that the ice is 300 m deep beneath the KPass plateau, and internal reflectors appear continuous and parallel (Figure 6). We expect that all 2009 GPR profiles and GPS velocity data will be analyzed by October, 2009, and Seth Campbell will be presenting these data at American Geophysical Union conference in December, 2009. Analysis to date indicates that the site at KPass, from an ice dynamics perspective, contains a straigraphically intact column of ice that should contain primarily vertical strain. This confirms our overall analysis based on ice stratigraphy, ice velocity, ice depth, accumulation rates, and logistics that KPass represents a viable deep ice core drill site in the Alaska Range.

Mt. Redoubt Eruption

The team identified a visible tephra layer in the snow pits at base camp and Kahiltna Pass at a depth of 40-50 cm in the snowpack (Figure 7). This layer undoubtedly

corresponds to one or more of a series of explosive eruptions from the nearby (300 km to the south) Mt. Redoubt volcano, which was active from March 22 to April 4, 2009. These layers were sampled at high resolution and at different elevations to investigate the glaciochemical signature of the volcano, and how tephra chemistry varies spatially. This will help us to identify previous eruptions from Mt. Redoubt in the ice core record (e.g. 1989, 1966, 1933), providing robust timescale control points.

Regional Glaciochemistry and Proxy Records

Annual layers in the snowpack at both sites have been identified based on the location of ice layers and seasonal fluctuations in stable isotope ratios (Fig. 2). Comparison of the stable isotope records from Kahiltna Pass and Russell Plateau show strong regional coherence (Fig. 8), suggesting that an isotope-based paleoclimate record from Kahiltna Pass will represent regional conditions. Our analysis indicates that the 23.12 m long record (13.14 m water equivalent) from Kahiltna Pass extends back to the summer of 2003, while the 18.33 m Mount Russell Plateau (8500') record (9.70 m water equivalent) extends back to the summer of 2006. From this preliminary analysis, we have identified annual snow accumulation and annual percent melt for both records. The Kahiltna Pass melt percent record is strongly correlated (r>0.9) with the number of warm summer days at Talkeetna, Cantwell, and Fairbanks (Fig. 9). This suggests that we will be able to develop a robust record of summer warmth back in time from stratigraphic analysis of a series of cores from this site.

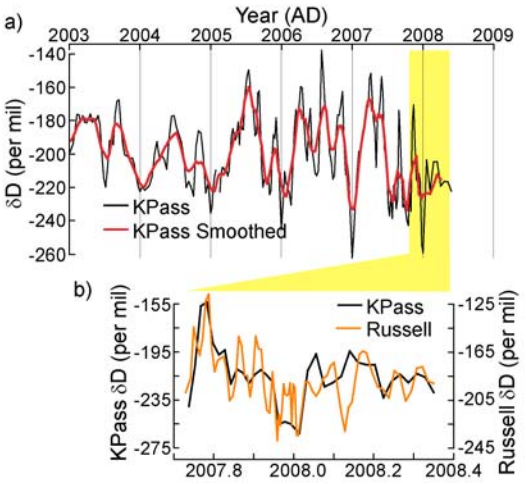

Fig. 8. (a) Hydrogen isotope record from KPass, and (b) KPass compared to Russell Plateau showing regional coherence.

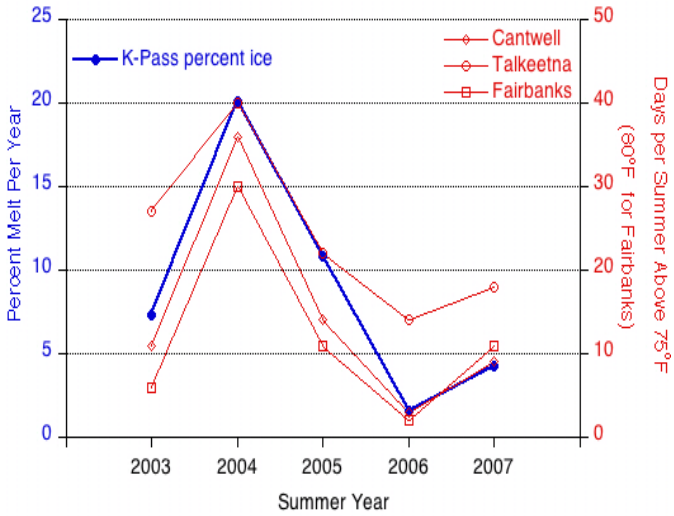

Fig. 9. Comparison of melt percent from the Kahiltna Pass with number of warm summer days at 3 weather stations

Trace element analyses of snow pit samples from Kahiltna Pass and Russell Plateau reveal elevated concentrations of Cd, Pb, Bi, As, Cu and Zn relative to crustal reference element concentrations (e.g. Al, Fe). These toxic metal(oid)s have crustal enrichment factors

ranging from 30-612, indicating that greater than 90% of each represents anthropogenic pollution. We do not see any evidence for local contamination of the Kahiltna Pass site by mountaineers, as trace metal concentrations and enrichment factors from the two sites are nearly identical over the last year (snowpit data). This is significant because Kahiltna Pass is close to the main route for climbers on Denali, whereas Russell Plateau is rarely visited. Thus, we are confident that trace metal records from Kahiltna Pass will represent regional atmospheric concentrations rather than local contamination.

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RESEARCH AND EDUCATIONAL ACTIVITIES:

1.1 2009 Project Goals

The primary objective of the overall University of New Hampshire (UNH), University of Maine (UMaine), and Dartmouth College research in central Alaska during the spring of 2009 was to follow-up on fieldwork conducted in May, 2008 to locate the best possible location for drilling a long (greater than 200 meters) surface-to-bedrock ice core in the central Alaska Range to develop a high-resolution, multi-parameter record of climatic and environmental change over the last several hundred years. The specific goals for the 2009 field program were to:

- Download data from the automatic weather station (AWS) installed in May, 2008 near the climber's base camp (7800') on the southwest fork of the Kahiltna Glacier. Reset the AWS for another year of data collection by extending the instrument pole and repairing or replacing any damaged or malfunctioning instruments.
- Collect snowpit samples at base camp and Kahiltna Pass (9500') spanning the previous year (May, 2008-May, 2009) to extend the glaciochemical records (snowpits and 20-m firn cores) collected in May, 2008, and to correlate with the AWS data spanning the same period.
- Collect additional ground (ice) penetrating radar (GPR) profiles at the potential deep-core site at Kahiltna Pass, and above and below the Kahiltna Pass site to characterize the ice depth and flow regime of the upper Kahiltna Glacier.
- Collect surface ice velocity data from the Kahiltna Glacier spanning from base camp to the region above Kahiltna Pass (10,500') using repeat global positioning system (GPS) surveys.
- Inform Denali National Park (DNP) staff and local citizens about our results from year 1 and plans for year 2.

1.2 Field Program - May 2009

During May 2009, our collaborative team of five scientists (two from the University of Maine, two from Dartmouth College, and one from Montana State University) traveled to DNP. On May 4, the team flew by fixed wing aircraft (Talkeetna Air Taxi Turbine Otter) into the climber's base camp (7800') for the west buttress route on Denali. We had been informed by Denali Park Rangers that our AWS was intact and appeared to be functioning in April, 2009, and we found the instruments partially buried when we arrived at base camp (Figure 1). This indicated to us that we needed to extend the AWS pole several feet higher for the 2009-2010 season than we had left it for the 2008-2009 season. All of the AWS instruments were intact and undamaged upon inspection. We dug out the AWS data recorder and downloaded the meteorological data onto a laptop. An initial analysis of the AWS data in the field revealed that all of the instruments had collected data for the full year, and were not obviously malfunctioning. We extended the AWS pole an additional 12 feet and added an additional 3 guy lines, for a total

of 6, to ensure that the higher pole remained stable. The AWS was then ready for another year of data collection (Figure 2). We subsequently dug a four meter deep snowpit to the previous summer ice layer in the vicinity of the AWS, and sampled the pit for glaciochemical analyses, density, and stratigraphy.

From base camp, we hauled our scientific equipment, gear, and supplies (Figure 3) to the Kahiltna Pass (9500') site where a potential deep ice core site was identified in 2008. Along the route, we installed a GPS base station (Trimble, provided by UNAVCO) on a nearby nunatak, and collected initial GPS position data on a series of stakes near the centerline of the Kahiltna Glacier. We had clear, sunny conditions for the 7 days at Kahiltna Pass (May 10-16), which was dramatically different from the low-visibility conditions encountered there in 2008. The improved weather allowed us to expand our GPS kinematic grid, GPR, and visual surveys 1 km to the south and 1.1 km to the north of the 2008 survey/drill location, and allowed us to gain a more complete assessment of the region as a potential deep core site. A total of 7.4 km of GPR data were collected (in addition to the 3.5 km collected in 2008) using a GSSI SIR-3000 unit and 100 MHz antenna (Figure 4) loaned on a collaborative basis from Dr. Steve Arcone (U.S. CRREL). A total of 40 staked positions were measured by GPS as part of the surface velocity survey, with the initial and repeat surveys separated by 5 days (May 9-11 to May 14-16) to allow quantifiable flow. In addition, high-resolution digital photographs were taken from the surrounding ridgeline from which we intend to develop a digital elevation model of the region. A four meter deep snow pit was sampled for glaciochemistry, stratigraphy and density on a plateau located ~750 m north of the 2008 pit and core site on Kahiltna Pass. All snow samples were stored in ISC boxes buried in two meter deep pits to keep them frozen.

We shuttled our equipment and supplies from Kahiltna Pass back to base camp on May 15 and 16. We re-inspected the AWS to ensure that it was stable and functioning after a week of operation (there was a strong wind storm on May 10-13), and returned to Talkeetna via fixed wing aircraft on May 17th. Snowpit and surface snow samples were stored in a local freezer in Talkeetna on May 17-18th, and flown to the University of Maine freezer by commercial aircraft along with the team members on the 19th. These samples are currently being analyzed at UMaine for stable isotopes, major ions, and trace elements.

1.3 Presentation of results and data dissemination

Analyses of all of the snow pit samples collected in 2009 are being analyzed for stable water isotopes and trace elements during the summer and fall of 2009. These records will be added to the longer (firn core) glaciochemical record from KPass spanning from 2003-2008. Once the GPR and GPS velocity data are analyzed, we intend to develop a flow model for the upper Kahiltna Glacier. The AWS station data will be analyzed and compared to other central Alaska meteorological stations to determine the degree to which Denali weather is indicative of regional weather patterns. The snow depth sensor data from the AWS will allow us to develop a high-resolution time scale for the snow pit chemistry spanning from 2008-2009. We will then be able to evaluate the influence of meteorological conditions on snow chemistry and melt stratigraphy, and compare the chemistry time series to regional aerosol monitoring stations. This analysis will be conducted by Dr. Osterberg and his student, Mr. Callahan, and presented at the fall AGU meeting in December, 2009. As discussed above, the Denali melt percentage proxy record for summer temperature will also be presented by Mr. Kelsey and Dr. Wake at AGU, as will the GPR profiles and GPS velocity results by Mr. Campbell and Dr. Kreutz. Dr. Kreutz is

also presenting Denali snowpit results (Pb isotope data) in conjunction with other data from the St. Elias Range, placing Central Alaska in a larger regional context with respect to Asian pollutant transport in the mid-troposphere. Dr. Kreutz is also giving an invited presentation at the Fall AGU 2009 meeting highlighting the evolution of Pacific climate variability over the past millennium, specifically the relationship among climate phasing in the North, tropical, and South Pacific sectors during the Medieval Climate Anomaly/Little Ice Age transition.

We have been in contact with Bruce Bauer at the NCDC Paleoclimatatology Branch regarding setting up an online data archive. He is in the process of establishing a project website, and we will populate the site with project datasets (glaciochemical, meteorological, and geophysical) as soon as final checks and publication have occurred.

Figure 1. Digging out the partially buried AWS at base camp on May 4, 2009.

Figure 2. Base camp AWS on May 6, 2009 after downloading data and elevating the instruments for a second year of data collection. Three additional guy wires were attached for added stability when the snowpack melts during the summer.

Figure 3. Hauling gear to Kahiltna Pass.

Figure 4. Collecting GPR prodiles on the Kahiltna Pass plateau using a GSSI SIR-3000 unit with a 100 MHz antenna.

Figure 5. Panoramic photo of the Kahiltna Pass plateau (9500') surrounded by a low ridge on three sides. The view is down-glacier towards the south.

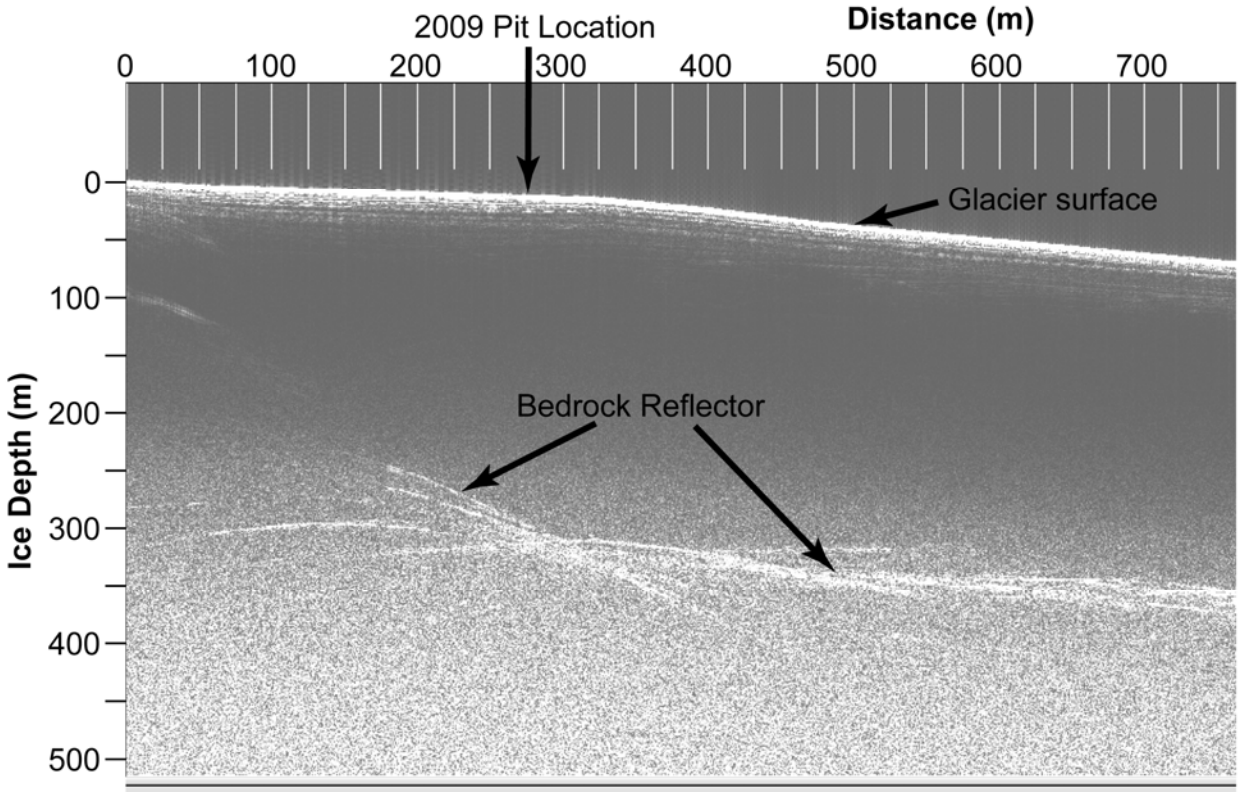

Figure 6. GPR profile from Kahiltna Pass Plateau, showing 300 m of ice at the 2009 pit location, and parallel internal stratigraphy.

Figure 7. Visible tephra layer (5 cm thick) in the snow pit wall at 40-50 cm depth from the March 22-April 4 explosive eruptions of Mt. Redoubt, AK.